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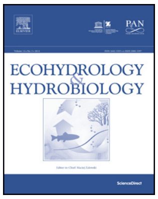

Original Research Article

Combined effect of soil bund with biological soil and water conservation measures in the northwestern Ethiopian highlands

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ABSTRACT

Excessive runoff and soil erosion in the upper Blue Nile Basin poses a threat that has attracted the attention of the Ethiopian government because of the serious on-site effects in addition to downstream effects, such as the siltation of water harvesting structures and reservoirs. The objective of the study was to evaluate and recommend effective biophysical soil and water conservation measure(s) in the Debre Mewi watershed, about 30 km south of the Lake Tana. Six conservation measures were evaluated for their effects on runoff, soil loss, and forage yield using runoff plots. There was a significant difference between treatments for both runoff and soil loss. The four-year average annual soil loss in the different plots ranged from 26 to 71 t ha^{-1}, and total runoff ranged from 180 to 302 mm, while annual rainfall varied between 854 mm in 2008 and 1247 mm in 2011. Soil bund combined with elephant grass had the lowest runoff and soil loss as compared to the other treatments, whereas the untreated control plot had the highest for both parameters. As an additional benefit, 2.8 and 0.7 t ha^{-1} $year^{-1}$ of dried forage was obtained from elephant and local grasses, respectively. Furthermore, it was found that soil bund combined with *Tephrosia* increased soil organic matter by 13% compared to the control plot. Soil bund efficiency was significantly enhanced by combining them with biological measures and improved farmers' perception of soil and water conservation measures.

1. Introduction

The extent of land degradation in Ethiopia has been described as a pressing challenge for the country's economy (Hurni, 1993). Two million hectares of land had been severely degraded (Jagger and Pender, 2003) and the amount of soil loss from all land use types in Ethiopia and Eritrea has been estimated as 1.5 billion ton annually, corresponding to an average of 42 t ha^{-1} $year^{-1}$ (Hurni, 1987). In the study area, Zegeye et al. (2010) found about 36 t ha^{-1} of soil loss annually from cultivated lands. Hurni (1993) estimated an annual crop yield reduction of 1–2% in Ethiopia due to soil erosion compared to 0.3% of global

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average (den Biggelaar et al., 2003). Moreover, soil erosion leads to off-site effects such as the siltation of lakes, reservoirs, and rivers. Accordingly, the cost of land degradation in Ethiopia is high (Bojö, 1996).

Despite the long term prevalence of land degradation, the Ethiopian government has become aware of the problems only after the extended droughts of 1973/1974 and 1984/1985 (Krüger et al., 1997). Since then, great efforts have been undertaken to conserve soil and water resources (Gebremichael et al., 2005; Herweg and Ludi, 1999; Sutcliffe, 1995). Such conservation efforts have been reversing the situation of land degradation in the country. For example, Herweg and Ludi (1999) summarized soil and water conservation (SWC) results achieved in 7 study sites of the former Soil Conservation Research Program (SCRP) in Ethiopia. They showed a significant reduction of soil and water loss as a result of applied conservation measures. Gebremichael et al. (2005) found that stone bunds in the Tigray region, northern Ethiopia, led to a 68% reduction of annual soil loss. Likewise, in Tigray, Vancampenhout et al. (2006) observed a yield increase of 7% on land treated with stone bunds compared to untreated areas.

Research and development services in Ethiopia have focused only on physical SWC structures without integrating biological measures. Moreover, the adoption of these physical structures by farmers has been continued as a challenge due to the land occupied by physical SWC structures such as soil bunds which they perceived as land loss (Million and Kassa, 2004; Damtew, 2006; Kassie et al., 2008; Adimassu et al., 2012). Hence, rigorous research to enhance the efficiency and productivity of soil bund combined with biological measures is critically important. Selection of plant species that could be integrated with soil bund for their wider adaptability, better economic value and efficiency to reduce soil erosion is highly demanded (Adimassu et al., 2012).

The efficiency of vetiver grass, elephant grass, and *Tephrosia* have been rarely studied for enhancing physical SWC measures such as soil bund in Ethiopia. Vetiver grass was introduced in 1971 from Tanzania and then widely distributed throughout Ethiopia (Kebede and Yaekob, 2009). Babalola et al. (2007), Dalton et al. (1996), and Grimshaw (1993) reported about the importance of vetiver grass in reducing soil erosion. In addition to the suitability study of elephant grass for gully rehabilitation by Alemu et al. (1997) and Yitaferu (1998), about 17.7 t ha^{-1} $year^{-1}$ dry biomass can be produced (Zewudu and Hassen, 1998). According to Guto et al. (2011, 2012) the nature of root and shoot structure of elephant grass helped to conserve soil and water better than *Leucaena*. *Tephrosia* is a nitrogen-fixing shrub that has been introduced from Kenya for green manure purpose. It has shown wider adaptability with high biomass yield that could be used as a green manure (Feyisa et al., 2007).

Therefore, to enhance the productivity of physical structures such as soil bunds and to increase the adoption rate of SWC technologies by the farmers, evaluating the combined effect of soil bund with biological SWC measures is the objective of this paper.

2. Materials and methods

2.1. Description of the study area

The experiment was conducted in the Debre Mewi experimental watershed, located at 11°20′13″ N and 37°25′55″ E (Fig. 1) which is 30 km south of Bahr Dar city along the road to Mota. Geographically, the watershed belongs to two districts: Yilmana Densa and Bahr Dar Zuria, in West Gojam administrative zone of Amhara Region. It drains to Blue Nile River. It has a unimodal type of rainfall with an average annual of 1240 mm, while the minimum and maximum monthly temperatures are 9.3 °C and 25.7 °C, respectively. June, July and August receive the largest shares of the annual rainfall.

The local geology is characterized by volcanic basalt flows and Cenozoic pyroclastic fall deposits (Abiy, 2009). The dominant soil types are nitisol, vertisol, and regosol. Nitisols dominate the upper parts of the watershed and are highly suitable for crop production. Vertisols are widespread in the lower parts of the watershed and are used for growing teff (*Eragrostis tef*), chick pea (*Cicer arietinum)* and grass pea (*Lathyrus sativus*). Regosols occur on the steep and highly eroded parts of the watershed. The watershed suffers from rapidly expanding active gullies (Tebebu et al., 2010), as well as sheet and rill erosion on all cultivated slopes (Zegeye et al., 2010). Cultivated land covers more than 70% of the watershed, and the remaining portion of the watershed is covered with communal grazing areas, bush lands, eucalyptus woodlots. The area is characterized by a small-scale crop and livestock mixed farming system. While it is one of the most productive areas in the country, it also faces a critical shortage of animal feed.

2.2. Design of experimental plots

Six different treatments: control (without any treatment), soil bund alone, and soil bund combined with *Tephrosia* (*Tephrosia vogelii*), vetiver grass (*Vetiveria zizanioides*), elephant grass (*Pennistum purpureum*), and a local grass called sembelet (*Hyparrhenia rufa*), respectively were evaluated for their effects on soil loss and runoff reduction at 10% slope field. The experimental plots (Fig. 2) were designed according to Herweg and Ostrowski (1997). Each of the treatments was tested on an area of 180 m^2, similar to the dimensions of the experimental plots used in the SCRP studies (Adimassu et al., 2012; CDE, 2000). To prevent flood into the plots, a cut-off drain was constructed at the head of the experimental plots. Between plots, sheets of corrugated iron were inserted 10 cm into the ground and protruded 20 cm above the ground to prevent runoff and sediment flow into and from the plot. At the lower end of each plot, two rectangular tanks having a capacity of 0.6 m^3 and 0.8 m^3 were installed for sediment and runoff collection. The larger tank (Tank 2) was used to collect an overflow from Tank 1 (Fig. 2). The tanks were made of sheets of iron. For each plot, runoff and sediments from the plot were channeled into the first tank through two inlet tubes. Runoff and suspended sediment from over flow of Tank 1 passed through the slot divisor. Ten per cent of the overflow from Tank 1 was collected in Tank 2 while